

CLAIMS

Therefore, having thus described the invention, at least the following is claimed:

- 1 1. An apparatus for determining *in situ* pore fluid and soil properties, the apparatus
2 comprising:
3 a penetrating tip member configured to penetrate the soil; and
4 an attachment module coupled to the penetrating tip member, the attachment
5 module including at least one mandrel, the at least one mandrel including at least one
6 piezo sensor,
7 wherein the at least one piezo sensor obtains an *in situ* measurement of pore
8 pressure at a location corresponding proximal to the at least one mandrel on the
9 attachment module.

- 1 2. The apparatus of claim 1, wherein the attachment module further comprises a
2 hollow inner chamber for containing data and power components.

- 1 3. The apparatus of claim 1, wherein the penetrating tip member further comprises
2 a conventional cone penetration testing (CPT) module.

- 1 4. The apparatus of claim 1, wherein the attachment module further comprises at
2 least one load cell, the load cell being coupled in sequence to the mandrel,
3 wherein the at least one load cell obtains an *in situ* measurement of interface
4 strength at a depth that proximal to the location of the at least one load cell.

- 1 5. The apparatus of claim 4, wherein the at least one piezo sensor is coupled
2 adjacent to at least one load cell, the at least one piezo sensor being isolated to
3 measure the pore fluid pressure generated for the at least one load cell, wherein a
4 friction sleeve associated with the at least one load cell induces an internal
5 shearing of the soil which enables the piezo sensor to measure pore fluid pressure.

1 6. The apparatus of claim 4, wherein the at least one load cell further comprises
2 a friction sleeve configured with a surface texture, where the surface texture has a
3 corresponding surface roughness value;

4 wherein each of the surface textures for select friction sleeves is configured
5 to induce internal shearing of the soil as the attachment module penetrates the soil
6 and to be self-cleaning, such that soil particles do not adhere to a surface of the
7 friction sleeve.

1 7. The apparatus of claim 6, further comprising a vertical arrangement of the friction
2 sleeves in ascending order according to increasing roughness of the surface texture, such
3 that the least rough friction sleeve is placed closest to the penetrating tip member and the
4 roughest friction sleeve is placed furthest away from the penetrating tip member.

1 8. The apparatus of claim 1, wherein the at least one piezo sensor produces a
2 signal at a corresponding depth in a single sounding, and the signals correspond to
3 individual *in situ* measurements of pore fluid pressure at the corresponding depth.

1 9. The apparatus of claim 1, wherein pore fluid pressure measurements from the
2 attachment module are transmitted to a data acquisition system.

1 10. The apparatus of claim 6, wherein the friction sleeves have an average surface
2 roughness of approximately 0.05 to approximately 250 μm .

1 11. The apparatus of claim 6, wherein each of the friction sleeves comprises a
2 surface texture that is characterized by geometric parameters, including height,
3 diagonal spacing, penetration angle, and width.

1 12. The apparatus of claim 11, wherein the geometric parameters of each of the
2 surface textures comprise height variations from approximately 0.25 mm to
3 approximately 2.0 mm, diagonal spacing from approximately 4.6 mm to approximately
4 12.5 mm, and penetration angles from approximately 30 degrees to approximately 120
5 degrees.

1 13. The apparatus of claim 3, further comprising a data acquisition system, the data
2 acquisition system comprises:

3 means for measuring penetration depth of the penetrating tip member and the
4 attachment module;

5 means for obtaining penetrating tip member measurement values;

6 means for measuring verticality of the penetrating tip member; and

7 means for obtaining pore fluid pressure values at each measurement increment on
8 each piezo sensor located in the mandrel; and

9 wherein the data acquisition system enables contemporaneous review of pore fluid
10 pressure data.

1 14. The apparatus of claim 13, wherein the measurement data from each of the
2 means for measuring is converted to digital signals, multiplexed, and then relayed to
3 the data acquisition system.

1 15. A method of determining *in situ* pore fluid and soil properties, the method
2 comprising the steps of:

3 positioning a penetrating tip member so as to penetrate into the soil at a particular
4 subsurface area;

5 positioning an attachment module in a predetermined relationship to the
6 penetrating tip member to form a penetrometer;

7 forcing the penetrometer into the soil beginning with the penetrating tip member;
8 and

9 collecting attachment module measurements from at least one piezo sensor
10 coupled to at least one mandrel,
11 wherein the piezo sensor obtains an *in situ* measurement of pore fluid pressure at a
12 depth that corresponds to the location of the at least one mandrel.

1 16. The method of claim 15, wherein collecting attachment module measurements
2 is performed by at least one individual load cell, the load cell including a friction
3 sleeve that measures an interface resistance, the interface resistance corresponding to
4 interface strength.

1 17. The method of claim 15, wherein collecting attachment module measurements
2 from a plurality of load cells comprises providing each of the load cells a corresponding
3 plurality of mandrels and friction sleeves, the plurality of friction sleeves being
4 configured to be removable, such that the arrangement of the friction sleeves along the
5 attachment module portion of the penetrometer may be reconfigured into different order
6 arrangements for measuring corresponding interface resistances of the friction sleeves.

1 18. The method of claim 16, wherein collecting attachment module measurements
2 from a plurality of load cells comprises each load cell with a friction sleeve configured
3 with a surface texture, the surface texture of select friction sleeves being configured
4 with a diamond-shaped pattern so as to induce internal shearing of the soil around the
5 penetrometer as the penetrometer is penetrated into the soil.

1 19. The method of claim 16, wherein collecting attachment module measurements
2 from a plurality of load cells comprises arranging a plurality of friction sleeves, wherein
3 the friction sleeves are arranged in ascending order of vertically according to increasing
4 roughness of the surface texture, such that the least rough friction sleeve is placed
5 closest to the penetrating tip member and the roughest friction sleeve is placed furthest
6 away from the penetrating tip member.

1 20. The method of claim 15, further including the steps of:
2 measuring penetration depth of the penetrometer;
3 measuring penetration tip member values;
4 measuring verticality of the penetrating tip member, where the penetration
5 depth, penetration tip member values, and verticality measurements comprise the drive
6 tip measurements; and
7 measuring pore fluid pressure at each measurement increment on each piezo
8 sensors located in the mandrel.

1 21. The method of claim 20, further comprising converting analog measurement
2 data from each of the measurements to digital signals, multiplexing, and then relaying
3 the multiplexed data to the data acquisition system.

1 22. The method of claim 16, further comprising isolating the piezo sensor to
2 measure the pore fluid pressure generated for each load cell, wherein the friction sleeve
3 of each load cell induces an internal shearing of the soil which enables the piezo sensor
4 to measure the pore fluid pressure induced by each friction sleeve of the individual load
5 cells at a particular subsurface.

1 23. The method of claim 15, further comprising collecting penetrating tip
2 measurements.